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Biophysical microgravity research on the International Space Station using biological materials has been ongoing for several decades. The well-documented substantive effects of long duration microgravity include the facilitation of the assembly of biological macromolecules into large structures, e.g., formation of large protein crystals under μ -gravity. NASA is invested not only in understanding the possible physical mechanisms of crystal growth, but also promoting two flight investigations to determine the influence of μ -gravity on protein crystal quality. In addition to crystal growth, flight investigations to determine the effects of shear on nucleation and subsequent formation of complex structures (e.g., crystals, fibrils, etc.) are also supported. It is now considered that long duration microgravity research aboard the ISS could also make possible the formation of large complex biological and biomimetic materials. Investigations of various materials undergoing complex structure formation in microgravity will not only strengthen NASA science programs, but may also provide invaluable insight towards the construction of large complex tissues, organs, or biomimetic materials on Earth.